GCE A LEVEL MARKING SCHEME

SUMMER 2023

A LEVEL
PHYSICS – COMPONENT 3
A420U30-1

INTRODUCTION

This marking scheme was used by WJEC for the 2023 examination. It was finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conference was held shortly after the paper was taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conference was to ensure that the marking scheme was interpreted and applied in the same way by all examiners.

It is hoped that this information will be of assistance to centres but it is recognised at the same time that, without the benefit of participation in the examiners' conference, teachers may have different views on certain matters of detail or interpretation.

WJEC regrets that it cannot enter into any discussion or correspondence about this marking scheme.

GCE A LEVEL PHYSICS

COMPONENT 3 – LIGHT, NUCLEI AND OPTIONS

SUMMER 2023 MARK SCHEME

GENERAL INSTRUCTIONS

The mark scheme should be applied precisely and no departure made from it.

Recording of marks

Examiners must mark in red ink.

One tick must equate to one mark (except for the extended response questions).

Question totals should be written in the box at the end of the question.

Question totals should be entered onto the grid on the front cover and these should be added to give the script total for each candidate.

Marking rules

All work should be seen to have been marked.

Marking schemes will indicate when explicit working is deemed to be a necessary part of a correct answer.

Crossed out responses not replaced should be marked.

Credit will be given for correct and relevant alternative responses which are not recorded in the mark scheme.

Extended response question

A level of response mark scheme is used. Before applying the mark scheme please read through the whole answer from start to finish. Firstly, decide which level descriptor matches best with the candidate's response: remember that you should be considering the overall quality of the response. Then decide which mark to award within the level. Award the higher mark in the level if there is a good match with both the content statements and the communication statement.

Marking abbreviations

The following may be used in marking schemes or in the marking of scripts to indicate reasons for the marks awarded.

cao = correct answer only
ecf = error carried forward
bod = benefit of doubt

SECTION A

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1	(a)		The [minimum] distance between successive / adjacent (1) points oscillating in phase / equivalent points / compressions / rarefactions / <u>pressure / displacement</u>-peaks or troughs (1) i.e. distance between successive peaks - only 1 mark **OR** minimum distance between successive / adjacent (1) Wavefronts (1)	2			2		
	(b)	(i)	λ is the distance travelled in one period (1) And $\text{speed} = \frac{\text{distance}}{\text{time}}$ (1) **OR** Frequency = $\frac{1}{T}$ (1) Distance in 1 s = no. of waves per sec $\times$ wavelength (be generous) (1) If they start from $v = f\lambda$ allow 1 mark for frequency = $\frac{1}{T}$ (1)	2			2	1	
		(ii)	Distance travelled = 180 [m] (1) Speed = $\frac{180}{0.51}$ = 350 **or** 353 [m s^{-1}] (1) (correct answer implies 1st mark because "calculate") Allow 1 mark for 175 **or** 176 **or** 180 [m s^{-1}]		2		2	1	2
		(iii)	Period = $\frac{7.55}{20}$ **OR** freq = $\frac{20}{7.55}$ (0.38 s, 2.65 Hz) (1) Substitution into $c = \frac{\lambda}{T}$ **OR** $c = f\lambda$ (1) **ecf** on c (don't penalise c = 330 **or** 340 **or** similar) Correct answer = 133 [m] (1)	1	1 1		3	2	3

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(iv)	Strobe frequency is wrong (1) Appears stationary at half frequency (or multiples of period) (1) So counting and timing method better (must be linked to some good physics) (1) **Alternative:** Student miscounted accept “human error” (1) Counted half oscillations (1) And the stroboscope is better (must be linked to some good physics) (1) **Alternative: 2 marks max** bad calibration / systematic error of strobe (1) So counting and timing method better (must be linked to some good physics) (1) **Alternative: 2 marks max** Because 7.55 ± 0.1ish or 1.3 ± 0.1 (1) Hence, timing is better (1)			3	3	1	3
			Question 1 total	**5**	**4**	**3**	**12**	**5**	**8**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	(a)		A good attempt at any sized diffraction pattern (1) (No marks for double slit pattern) Wavefronts nearly semi-circular centred at the slit and no lines crossing or touching (1) Wavelength remains constant throughout (by eye) (1) **Ignore any arrows for wave direction**	3			3		
	(b)		Lines or slits cause light to spread (accept diffract) (1) So rays / light can overlap / interfere / cross paths / superpose (1) In general, no mention of slits / lines / equivalent – no marks Exception – diffracted **waves** spread out allowing them to interfere. This is worth 1 mark. The plural “waves” implies many lines but the answer should have stated this.		2		2		
	(c)	(i)	$\tan\theta = \frac{\left(\frac{357.9}{2}\right)}{250}$ (1) Angle = 35.60° (1) Substitution i.e. $2\lambda = d\sin 35.60$ (1) Applying no. of lines per cm = $\frac{1}{d}$ (1) Correct answer = 4491 **OR** 4490 **OR** 4492 [lines per cm] (1) (correct answer implies all previous because “calculate”) Allow 4 marks for 6326 ± 1 (lines/cm) (expect 55.06°)	1	1 1 1 1		5	5	5

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
			Alternative for max 3 marks $\lambda = \frac{ay}{D}$ used (1) Gives a = 1.8 × 10^{-6} [m] (do not penalise power of 10 errors here) (1) Final lines per cm = 5523 ± 1 (1) **Max of 4 marks** for: Incorrectly assuming n = 1 angle is half of n = 2 angle (diff grat MS applies) Expect: Angle = 19.69° Substitution into diffraction grating equation (1) Applying no. of lines per cm = $\frac{1}{d}$ (1) Lines per cm = 5200 ± 1 (1)						
		(ii)	Lowers percentage uncertainty (1) in lengths [and final answer] **OR** since absolute uncertainty is the same / resolution the same (1)			2	2		2
	(d)		**Any 3 × (1) from:** **Accept interference pattern for fringes** • Fringes are brighter for diff grat (dg) **OR** converse for double slit • Can be carried out without darkness **OR** converse for ds • Fringes are sharper / clearer for dg **OR** converse for ds • Distances can be larger / more precise / accurate **OR** converse for ds (accept measurements more precise because all measurements are distances) • Line spacing of dg more precise / accurate NOT – a more accurate fringe pattern			3	3		3
			Question 2 total	**4**	**6**	**5**	**15**	**5**	**10**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	(a)	(i)	0.940		1		1	1	1
		(ii)	**1st conclusion improvements (Helen)** Line passes through all error bars (1) Anything good relating to the shape of the curve e.g. gradient decreases **OR** maximum refraction angle / critical angle **OR** straight / proportional at start because $\sin\theta \approx \theta$ (1) NOT – total internal reflection Accept curves as expected OR correct / expected shape but not just "curve" **2nd conclusion improvements (Valentina)** LOBF is straight line through origin ACCEPT sin(i) proportional to sin(r) (1) All points close to LOBF **OR** through all error bars (1)			4	4		4
	(b)		Pair of points taken **or** gradient attempted (1) Refractive index =1.47-1.50 (1) Allow this mark if they calculate max-min and some part is in this range e.g. 1.45 ± 0.02 Gradient because it incorporates all readings OR similar e.g. using point towards right of LOBF smaller % unc / more precise (1) Accept – gradient gives average of values			3	3	2	3
			Question 3 total	**0**	**1**	**7**	**8**	**3**	**8**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	(a)	(i)	Anything in range 1 mm – 1 m **unit mark** Don't accept >1 mm OR <1 m but accept range within range e.g. $10\text{ cm} < \lambda < 15\text{ cm}$	1			1		
		(ii)	Anything in range 10 nm – 400 nm **unit mark** (penalise only once) Don't accept >10 nm OR <400 nm but accept range within range e.g. $200\text{ nm} < \lambda < 300\text{ nm}$	1			1		
	(b)	(i)	The <u>minimum</u> energy (1) To free an electron **OR** for an electron to escape (1) [surface of metal is in the question]	2			2		
		(ii)	Valid method for converting wavelength to energy i.e. application of $\frac{hc}{\lambda}$ (1) Valid method for converting J to eV i.e. dividing by e (1) **OR** quoting a few eV e.g. 3 eV = 4.8×10^{-19} [J] Correct eV of microwave **and** UV quoted (allow **ecf**) (1) [1.24 μeV-1.24 meV] [3.1 eV-124 eV] **OR** comparison of both UV and micro with e.g. 4.8×10^{-19} [J] **OR** 2 calculations for $E_{\text{k max}}$	1	1 1		3		

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(iii)	Use of $E = \frac{hc}{\lambda}$ (9.945 × 10^{-19} J) (1) Conversion from J to eV e.g. 5.1 × e **OR** $\frac{E}{e}$ (1) Correct use of Einstein's equation e.g. $E_{\text{k max}}$ = 1.785 × 10^{-19} [J] **OR** 1.12 [eV] (implied by correct final answer) (1) Rearrangement of KE equation e.g. $v^2 = \frac{2KE}{m}$ (1) Final answer = 6.26 × 10^5 [m s^{-1}] (1) (all previous marks implied by correct answer unless something demonstrably wrong) **Award 2 marks** for 1.5 × 10^6 [m s^{-1}]	1	1 1 1 1		5	5	
			Question 4 total	**6**	**6**	**0**	**12**	**5**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5			**Indicative content:** **Method** Increase pd gradually Until some value of current e.g. 30 mA **OR** until light seen Record pd Change LED Repeat process Wavelengths of LEDs known **Analysis** Electron energy = photon energy $\mathrm{eV} = \frac{hc}{\lambda}$ **OR** $\mathrm{eV} = hf$ Plot graph of V against $\frac{1}{\lambda}$ **OR** $\frac{1}{V}$ against λ **OR** V against f **OR** eV against $\frac{1}{\lambda}$ **OR** $\frac{1}{eV}$ against λ **OR** eV against f Get h from the gradient Correct equation for gradient and h i.e. gradient = $\frac{hc}{e}$ **OR** $\frac{e}{hc}$ **OR** $\frac{h}{e}$ **OR** hc **OR** $\frac{1}{hc}$ **OR** h Note – many good points are available even when candidates are discussing stopping potentials e.g. eV_s will be similar to the energy supplied to the electron in the LED **5-6 marks** Comprehensive description of method and analysis *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.*	6			6		6

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
			3-4 marks Basic description of comprehension and analysis **or** comprehensive of one only. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** Limited description of one or both **or** basic description of one only. *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **0 marks** No attempt made or no response worthy of credit.						
			Question 5 total	**6**	**0**	**0**	**6**	**0**	**6**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	(a)		Long lifetime / half-life **OR** equivalent **OR** forbidden transitions **OR** stays longer Don't accept NOT quite stable	1			1		
	(b)		Use of $\lambda = \frac{0.693}{T_{\frac{1}{2}}}$ (1) (gives 288.75) $\frac{5 \times 10^{18}}{288.75}$ seen **OR** 1.73×10^{16} seen **OR** $1.7 \times 10^{16} \times 289$ (1) Explanation that rate of pumping = rate of spontaneous dropping for equilibrium **OR** activity = pumping rate (1)		3		3	2	
	(c)		[Metastable] linked to population inversion / stimulated emission (1) [Larger population] gives higher output / more stimulated (1) Accept – more probable / easier for stimulated emission to occur Accept – less pumping required Accept – brighter for higher output Population is proportional to half-life (1)	1 1	1		3		
			Question 6 total	**3**	**4**	**0**	**7**	**2**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	(a)	(i)	Nucleon = 207 (1) Proton = 82 (1)		2		2		
		(ii)	$0.8 = e^{-\lambda t}$ **OR** $0.8 = \frac{1}{2^n}$ (1) correct substitution (accept $\frac{0.8}{0.9928}$ instead of 0.8) $\ln 0.8 = -\lambda t$ **OR** $\log 0.8 = n \log 0.5$ i.e. taking logs (1) Use of $\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$ **OR** no. half-lives = 0.322 (1) Expect 9.85×10^{-4} million-year $^{-1}$ **or** 3.12×10^{-17} s^{-1} **or** 9.85×10^{-10} yr^{-1} Final answer = 227 million-year **OR** 7.15×10^{15} s or equivalent correct answer **unit mark** (1)	1	1 1 1		4	4	
		(iii)	U235, 6.4 billion = 9.09 half-lives **OR** λ obtained for [U235 and] U238 (expect 0.155 billion $year^{-1}$ **OR** 4.91×10^{-18} s^{-1}) (1) U238, 1.43 half-lives **OR** rearrangement i.e. $N_0 = Ne^{+\lambda t}$ (1) Note: If 0.0018 and 0.37 seen award 1st 2 marks $1.5 \times \left(\frac{1}{2}\right)^{9.09}$ **OR** $0.72 \times 2^{9.09} = 392$ **OR** $0.72e^{+\lambda_1 \times 6.4}$ **OR** $1.5e^{-\lambda_1 \times 6.4}$ (1) $1 \times \left(\frac{1}{2}\right)^{1.43}$ **OR** $99.28 \times 2^{1.43} = 268$ **OR** $99.28e^{+\lambda_2 \times 6.4}$ **OR** $1e^{-\lambda_2 \times 6.4}$ (1) $\frac{392}{268} = 1.46$ so about right etc. (1) **Alternative 3:** λ obtained for [U235 and] U238 (1) $N_1 = N_0 e^{-\lambda_1 t}$ and $N_2 = 1.5 N_0 e^{-\lambda_2 t}$ (1) Dividing and using concentrations i.e. $\frac{N_2}{N_1} = \frac{99.28}{0.72} = \frac{1}{1.5} e^{-\lambda_2 t + \lambda_1 t}$ (1) Taking logs correctly i.e. $-\lambda_2 t + \lambda_1 t = \ln \frac{99.28 \times 1.5}{0.72}$ (1) Correct answer = 6.43 billion (1)			5	5	4	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
			Alternative 4 $2^{\frac{t}{4.47}}N_1 = N_0$ (1) $2^{\frac{t}{0.704}}N_2 = 1.5N_0$ (1) Dividing and using concentrations i.e. $2^{\left(\frac{t}{0.704}-\frac{t}{4.47}\right)}\frac{99.28}{0.72} = \frac{1}{1.5}$ (1) Taking logs correctly i.e. $\left(\frac{t}{0.704} - \frac{t}{4.47}\right)\ln 2 = \ln(\frac{0.72}{99.28\times 1.5})$(1) Correct answer = 6.43 billion (1)						
	(b)		**Any 3× valid points (1)** Examples of valid points: Alpha highly dangerous if <u>inhaled</u> due to <u>high ionisation</u> Unwise to go against planning officials / council Radon heavy gas / dense so goes to basements Radon gas can accumulate / increase concentration Radon concentration might be greater than 10× Smoking / asbestos is far more dangerous Councils were advised by experts / scientists Damp proof course provides protection Enters through cracks / leaks **OR** some brief explanation why rooms other than basements might be dangerous Only allow **one of the following** as valid number interpretation: Risk of lung cancer is low (0.4%-0.5%) Increase risk is only 0.1% or to 1 in 200 Risk of lung cancer increases by 25% **Don't accept:** Not - Cornwall or similar (10× normal in question) Not - open doors for ventilation (no good in winter)			3	3		
			Question 7 total	**1**	**5**	**8**	**14**	**8**	**0**

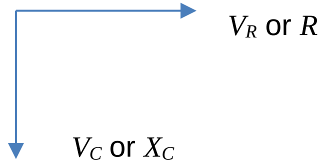
Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
8	(a)		BN applied once 1+1=1+1+0 (1) Accept 1+1 = 1 + 1 Accept uud + uud = uud + uud + ?? LN applied once 0+0=0+0+0 (1) Accept 0+0=0+0 Q applied once 1+1=1+1+0 (1) Accept 1+1=1+1 Conclusion: neutral pion/ π^0 /$\mathrm{u\bar{u}}$/ $\mathrm{d\bar{d}}$ (1) NOT photon **Alternative:** BN of X must be 0 (1) LN of X must be 0 (1) Q of X must be 0 (1) Conclusion: neutral pion (1)		4		4		
	(b)		Mass is equivalent to 67.5 MeV ×2 (1) Allow for ×2 seen $\times 1.6 \times 10^{-19}$ and $\div 9 \times 10^{16}$ **OR** $\div$ 931 and $\times 1.66 \times 10^{-27}$ (1) Correct answer = 2.41×10^{-28} [kg] (1) Allow 2 marks for 1.2×10^{-28} and 4.8×10^{-28} and 2.41×10^{-34} [kg]		3		3	3	
			Question 8 total	**0**	**7**	**0**	**7**	**3**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
9	(a)		Clockwise (1) Accept clockwise arrow at tangent [Fleming's] LHR (1) Accept Coulomb **OR** electrostatic attraction (of the positive alpha particle to the negative tube)	1	1		2		
	(b)		$\frac{mv^2}{r} = Bqv$ (1) Substitution (1) Answer = 0.04 [T] (1) Award 2 marks for 0.08 [T], 0.02 [T], 0.01 [T] Ignore any further calculation of flux	1	1 1		3	2	
	(c)		$T = \frac{2\pi r}{v}$ **OR** $m\omega^2 r = Bqv$ **OR** $\omega = \frac{Bq}{m}$ (1) $f = \frac{1}{T}$ **OR** $\omega = 2\pi f$ (1) i.e. $f = \frac{v}{2\pi r}$ **OR** $f = \frac{Bq}{2\pi m}$ scores first 2 marks Correct answer = $f \times 2$ = 606 k[Hz] (full **ecf** available on wrong m and q and B) (1) Note: 303 kHz is 2 marks as is 1.2 MHz	1	1 1		3	3	
	(d)		Use of $\frac{1}{2}mv^2$ (needs m or v substitution) (1) Correct conversion to eV i.e. dividing J by e (5.312 MeV) (1) Allow 1 mark for stopping at 8.5 × 10^{-13} [J] Allow 2 marks for 8.5 × 10^{-13} [J] = 5.3 M[eV] Allow 2 marks for $\frac{\frac{1}{2}\times 4\times 1.66\times 10^{-27}\times(1.6\times 10^{7})^2}{1.6\times 10^{-19}}$ Allow 2 marks even if calculated elsewhere e.g. in (c) If there is a slip present only allow 1 of 1st 2 marks If no evidence of dividing by e and answer is 5.3 MeV rather than 5.31 MeV – only allow 1st mark Explanation of how 4 accelerations and charge of 2e linked to 8 nV (1) Beware! Not 2 V × 4 Accept $V \times 2e \times 4$ – minimum explanation	1	1 1		3	2	
			Question 9 total	**4**	**7**	**0**	**11**	**7**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
10	(a)	(i)	Only vertical component cut **OR** only vertical component producing flux **OR** horizontal lines not cut **OR** the area is perpendicular to the vertical component **OR** normal of area is in perpendicular direction **OR** horizontal gives flux of zero **OR** flux due to horizontal doesn't change **OR** $\theta = 0$ for vertical lines **OR** $\cos\theta = 1$ for vertical lines **OR** $\theta = 90$ for horizontal lines **OR** $\cos\theta = 0$ for horizontal lines Not – current perpendicular to vertical magnetic field Not – motion is perpendicular to vertical magnetic field Not – horizontal component is parallel to motion / current		1		1		
		(ii)	Anticlockwise/ up in slider / down in resistor / down in ammeter etc. **OR** correct arrow on diagram (1) If up / down / left / right, must specify where Rule explained in sufficient detail (1) e.g. [F]RHR – sufficient OR [F]LHR & applied to electrons in slider OR [F]LHR combined with Lenz's (to reverse) OR right-hand grip rule & opposing / Lenz	1	1		2		
		(iii)	$V = Blv$ quoted **OR** derived **OR** equivalent (1) $I = \frac{V}{R}$ (to obtain 0.6 mV, implied by correct answer) (1) Correct answer = 45 μ[T] (1)		3		3	3	
	(b)		Rhianna wrong, current decreases (1) Because area / flux increases at a decreasing rate **OR** because rate of cutting decreases [in circuit] (1) **OR** because l decreases in Blv Accept – because the change in area gets smaller [per unit time] Accept – because $\Delta\Phi$ or ΔBA or ΔBAN etc. decreases Not – because area decreases Not – because current $\propto$ area			2	2		
			Question 10 total	**1**	**5**	**2**	**8**	**3**	**0**

SECTION B

Option A – **Alternating Currents**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
11	(a)	(i)	$X_L = X_C$ at resonance (1) $2\pi f L = \frac{1}{2\pi f C}$ and no mistakes in algebra (1)	1	1		2	1	
		(ii)	Substitution of 100 pF to get f_0 (1) Correct answer = 145 k[Hz] (1)		2		2	1	
		(iii)	$V_L = V_C$ at resonance **OR** all pd across R at resonance / min Z at resonance / $Z = R$ at resonance (1) $I = \frac{230}{47}$ seen (1)	1	1		2	1	
	(b)	(i)	Phasor diagram with X_C or V_C perpendicular to R or V_R (1) R or V_R leading C or V_C (default is anticlockwise but accept clockwise if stated) (1)  Resultant phasor drawn (1) Length of the resultant indicated to be $\sqrt{R^2 + X_C{}^2}$ **OR** $\sqrt{V_R{}^2 + V_C{}^2} = I\sqrt{R^2 + X_C{}^2}$ (1)	1 1 1	1		4	1	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(ii)	Substitution of $X_C = \frac{1}{\omega C}$ (1) Squaring seen leading to answer (1)		2		2	2	
		(iii)	Intercept = 4.8 (with tolerance of ± 0.1) (1) Hence, R = 2.2 [Ω] (1) Gradient = $4.5 \times 10^{10} \pm 0.1 \times 10^{10}$ (1) Gradient = $\frac{1}{C^2}$ (1) Final answer $C = 4.7 \times 10^{-6}$ [F] (1)			5	5	4	
		(iv)	As f increases, X_C decreases or vice versa (can be implied in answer) (1) Correct explanation of division of pds at low f (i.e. X_C is huge so V_R is negligible) (1) Correct explanation of division of pds at high f (i.e. at high frequency X_C very small so $V_R = V_{supply}$ or V_C = 0) (1)	1	1 1		3		
			Question 11 total	**6**	**9**	**5**	**20**	**10**	**0**

Option B – **Medical Physics**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
12	(a)	(i)	$V = \frac{7\,500}{0.25}$ = 30 000 [V] **or** 30 k[V]		1		1	1	
		(ii)	Line spectrum and background spectrum labelled (1) Use of $\lambda_{\text{min}} = \frac{hc}{eV}$ (1) **ecf** on V λ_{min} = 4.14 × 10^{-11} [m] or 0.0414 n[m] (value with correct multiplier) (1)	1 1	1		3	2	
		(iii)	Same shaped spectrum shifted up & to the left & spikes in same place (1) Method for calculation $\lambda_{\text{min}} = \frac{hc}{eV}$ (1) λ_{min} = 3.09 × 10^{-11} [m] **or** 30.9 p[m] ecf (1)		3		3	2	
		(iv)	No; and use of $E = \frac{hc}{\lambda}$ (1) If λ = 0, E is infinite (1) Accept V is infinite		2		2	2	
	(b)		1 mark for conclusion and reason for each technique e.g. Ultrasound B-scan would be best / simplest / quickest because cheapest and provides moving images (1) MRI good but more expensive (modern MRI produces moving images too) (1) X-rays poor due to bad soft tissue contrast / not moving images (but can diagnose calcification of valves) (1) CT similar to X-ray but higher dosage and better soft tissue contrast / 3D (1) Radioactive tracer - pointless (even if used with gamma camera, resolution far too low) / they don't give moving images (1)			5	5		

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(c)		Use of $\frac{\Delta\lambda}{\lambda} = \frac{2v\cos\theta}{c}$ (1) Rearrangement: $v = \frac{c\Delta\lambda}{2\lambda\cos\theta}$(1) v = 0.886 [m s^{-1}] (1)	1	1 1		3	3	
	(d)		Positron emitter injected/enters body **OR** positron emitter collects at point of interest/cancer (1) Positron-electron annihilation - gives 2 gamma rays (1) Detected in opposite directions **OR** detected with gamma cameras **OR** detected with time delay(s) (1)	3			3		
			Question 12 total	**6**	**9**	**5**	**20**	**10**	**0**

Option C – **The Physics of Sports**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
13	(a)		Principle of moments applied (1) Clockwise moments and anticlockwise moments correctly applied i.e. (95.8 $T \times$ cos24) + (126 × 38) = (820 × 22.3) (1) T = 154 [N] (1) If Tsin24 × 95.8 or F × 95.8 used correctly **–** award 2 marks	1	1 1		3	2	
	(b)		Moment of inertia is defined as $I = \sum m_i r_i^2$ (1) Where m_i is the mass and r_i is the distance from the axis of rotation (1) **OR** torque / angular acceleration 1 mark equation, 1 mark for terms	2			2		
	(c)	(i)	Angular momentum = $I\omega$ (1) Moment of inertia = 8.24 × 10^{-5} [kg m^2] (1) Angular momentum = 2.59 × 10^{-3} [kg m^2 s^{-1}] (1)	1	1 1		3	2	
		(ii)	Rotational kinetic energy = $\frac{1}{2}I\omega^2$ (1) Rotational KE = 1.82 [J] (**ecf** on moment of inertia) (1) Linear KE = 71.6 [J] – so correct (1)	1	1 1		3	2	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(d)	(i)	Horizontal distance = 19 – 8 = 11 [m] **OR** distance from batsman calculated to check answer (1) Vertical and horizontal components of velocity correct Vertically v = 6.26 [m s^{-1}]; Horizontally v = 44.56 [m s^{-1}] (1) Use of horizontal velocity to obtain time of flight, assuming 11 m (0.267s) [s] **OR** using vertical velocity to obtain time of flight through solving quadratic equation in time (0.265 s) (1) Checking vertical distance using time of flight **OR** checking horizontal distance using time of flight (1) Conclusion – Height is smaller so ball will land more than 8 m from batsman (1)			5	5	4	
		(ii)	Air resistance force shown correctly (opposite to motion) (1) “Lift” force shown correctly (should be 90º to motion) (1)	1	1		2		
		(iii)	Drag has greater effect on horizontal component so lands earlier (no ecf on drag direction) (1) Topspin provides downward force and so lands earlier (**ecf** on lift direction) (1)		2		2		
			Question 13 total	**6**	**9**	**5**	**20**	**10**	**0**

Option D – **Energy and the Environment**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
14	(a)	(i)		$340-(77+23+76)=164$ **OR** reflected = 76 + 23 (1) $\frac{77+164}{340}$ = 0.71 so correct **OR** $\frac{99}{340}$ = 0.29 and 1 - 0.29 = 0.71 (1) [so correct]			2	2	1	
		(ii)		[Greenhouse] gases [in atmosphere] absorb [far] infra-red radiation [and transmits visible and some near UV and IR] (1) [Absorbed infra-red] re-radiated to Earth / Earth's surface warming planet [to a higher temperature than without atmosphere] (1)	2			2		
		(iii)	I	[Increased] volume of transport / electricity production / industrial processes / burning of fossil fuels / agriculture (1) Leading to [increased] greenhouse gas emissions (1) More infra-red radiation absorbed or owtte (1)		3		3		
			II	Ice or snow melt / evaporation / permafrost melt (1) Ice or snow reflect less radiation or more radiation absorbed by what lies beneath / more water vapour in atmosphere / more methane released (1)		2		2		
	(b)			$I\cos\theta=350\cos 28=309$ (1) Sub into $I=\frac{P}{A}$ i.e. $309=\frac{P}{1.9}$ (1) [$P=587$ W] Sub into $\text{efficiency}=\frac{\text{useful energy [per second] transfer}}{\text{total energy [per second] input}}\times 100\%$ i.e. $\frac{128}{587}\times 100\%$ (1) Answer = 21.8 [%] or 0.218 (1) **ecf** on vertical component	1 1	1 1		4	4	

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(c)	(i)		Rate of energy transfer is <u>1.51</u> J s^{-1} (or W) (1) through an area of 1 m^2 for a temperature difference of 1 K [between the inside and outside of the external wall] (1)	2			2		
		(ii)	I	$A = \frac{P}{U\Delta\theta}$ with correct P and $\Delta\theta$ inserted e.g. $\frac{180}{1.51\times 10}$ (1) 11.9 [m^2] (1) **Alternative**: $\frac{\Delta P}{\Delta\theta} = [-]\ 18$ (1) $A = \frac{18}{U} = 11.9$ [m^2] (1)		2		2	2	
			II	Area of wall = 8.2 [m^2] **OR** P_{doors}= 51 [W] (1) P_{wall} = 65 – 51 = 14 [W] (1) $U = \frac{P}{A\Delta\theta}$ = 0.17 [W m^{-2} K^{-1}] (1) [< 0.2 so Charlie is correct] Accept alternative methods using 0.2 [W m^{-2} K^{-1}] to calculate U_{door} **OR** $P_{\text{wall+door}}$			3	3	3	
				Question 14 total	**6**	**9**	**5**	**20**	**10**	**0**

A LEVEL COMPONENT 3: LIGHT, NUCLEI AND OPTIONS

SUMMARY OF ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
1	5	4	3	12	5	8
2	4	6	5	15	5	10
3	0	1	7	8	3	8
4	6	6	0	12	5	0
5	6	0	0	6	0	6
6	3	4	0	7	2	0
7	1	5	8	14	8	0
8	0	7	0	7	3	0
9	4	7	0	11	7	0
10	1	5	2	8	3	0
11	6	9	5	20	10	0
12	6	9	5	20	10	0
13	6	9	5	20	10	0
14	6	9	5	20	10	0
TOTAL	**36**	**54**	**30**	**120**	**51**	**32**